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A Challenging Edinburgh Fossil Site

Wardie, 1842.

Produced by ‘Mr Wood's Fossils’, Edinburgh

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Front cover : Looking North-east over Area 'C' with Old Chain Pier (demolished 1896) and Island of Inchkeith.

Engraving : H. Bartlett, 1842.

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[Wood, Stan P]

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GRANTON AND WARDIE SHORE

INTRODUCTION

Once upon a time a local Edinburgh lad of 30 years itching for further stimulus, found that searching for fossils in and around Scotland's capital provided an ideal 'run off' for physical and mental excesses. The challenge of a new locality, the anticipation of finds, their moment of discovery, the triumphant return home; all for the cost of a local bus fare. Happily that value for money is just as true today as it was then. If, as I did, you too become immersed in this intriguing hobby, then even the pain of a back bent for more hours than advisable, the penetrating cold from North Sea winds and the throbbing ache of unintentionally hammered knuckles, will only add depth to the satisfaction of a new specimen won through adversity.

The locality known as Wardie Bay is chosen here because it is convenient to the visitor who can board a bus in Edinburgh's Princes Street and alight at Lower Granton Road 15 minutes later virtually on sight. This locality provides a unique opportunity to collect fossil fishes within the boundaries of a major British city and without trespass! However as the site may in due course be elevated to the status of 'Site of Special Scientific Interest', certain conditions pertaining to random collecting may be statutory in the future. Treat this locality as a challenge and you won't be disappointed. It will thwart you, frustrate you, perhaps even deject you. I avoided the latter by perseverance as it took me two years to see the first fossil fish of my collecting life come to light here. At this demanding locality frustration should be considered but a prologue to elation, the more intense the former the more excessive the latter!

GEOLOGY OF WARDIE BAY

Before taking a walk along the beach let's consider the environment prevailing when the shales and other rocks were being formed. This will explain why we find certain fossils at this locality and not others. In this respect Wardie Bay is no different from every other fossil bearing locality. The time is approximately 340 million years ago, the climate is sub-tropical, a lake occupies the site, stretching out over a 15-25 km area. This prehistoric lake is known as Lake Cadell, named after a Geological Survey officer, now deceased, whose work in Scotland is still much respected. Close to sea level the lake, whose margins and valley slopes are heavily foliaged exclusively in green, is accumulating fine muds at depth. The rate of accumulation is sufficiently fast to cover dead fishes before their carcasses disintegrate or are dispersed by bottom currents. Occasionally drifting plant debris becomes waterlogged, sinks and is entombed by sediment.

At Wardie, the shales also carry within their ranks other rock types namely sandstone, limestone and tuff. How does this tie in with the above scenario? This consideration heralds the input of a time dimension fundamental to our comprehension of the factors involved. Today at Wardie the rocks exposed are about 40-45m thick in total, and represent many tens of thousands of years in the lake's life as a depository of

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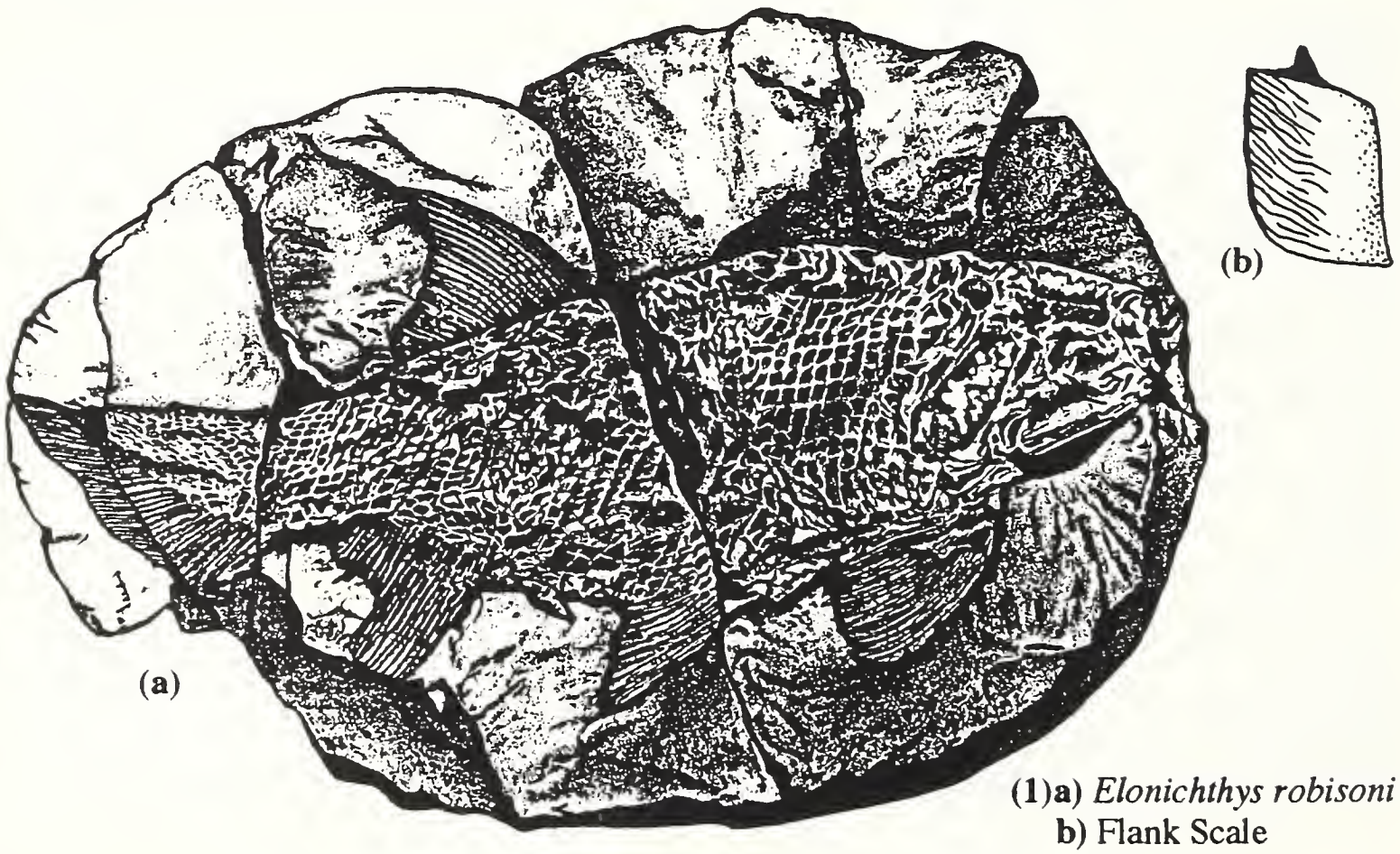
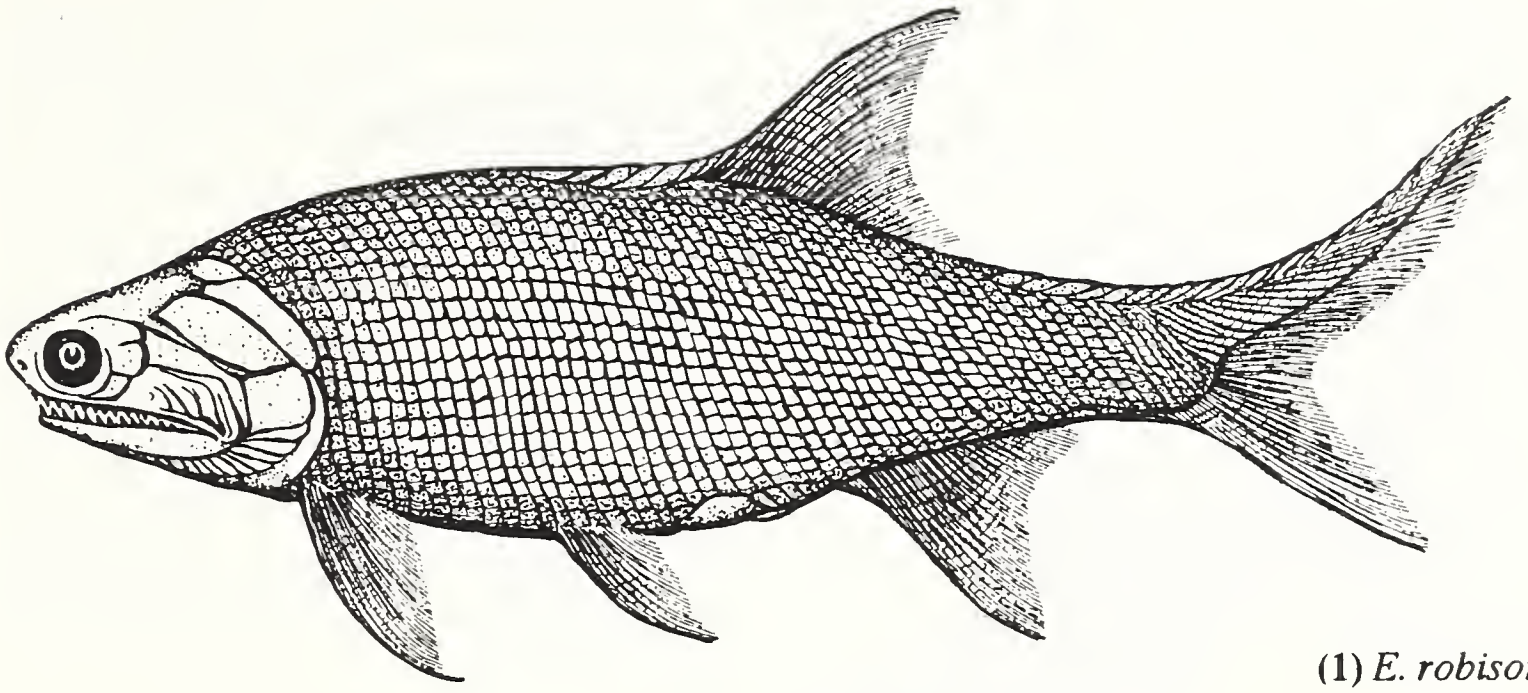
sediment. Shales formed when the lake was relatively deep at Wardie and sandstones when it was probably shallower or prone to faster currents. A thin coal layer also present at Wardie suggests the lake temporarily shrunk from the vicinity allowing the establishment of a local forest. In turn this vigorous vegetation was overwhelmed as the lake expanded once more and transgressed the area. A neighbourly sea, never far away and at approximately the same level, made the occasional saline incursion into lake waters. One of these marine forays is indicated by a shrimp-bearing limestone deposit and another has left behind some marine fossils within the shales themselves. The origin of a thin yellow band of rock only a couple of centimetres thick is worthy of mention here even though it is unfossiliferous. It's comprised of tuff, a fine grained ashy material, probably belched out over this part of the lake by a nearby volcano. Indeed, volcanoes were active on both sides of what is now Fife Region to the north and Lothian Region to the south, this part of Scotland being very unstable throughout the period. Persistant yielding of the Earth's crust encouraged hundreds of metres of sediment to accumulate under the lake bed without silting the latter out of existence. These vast depths of sediment, much of it fine grained, indicate a lake of considerable longevity even by geological standards. The Wardie rocks represent but a fraction of this accumulation and only a small period during the first half of Lake Cadell's life.

FOSSILS

The fossils found at Wardie Bay are therefore about 340-345 million years old and belong to the early part of the Carboniferous era in the geological time scale (200 million years before dinosaurs dominated the landscape). The fossil fishes are usually black in colour and are embedded in dark coloured rocks. Natural weathering of host rocks produces warm browns, maroons and even reds in the ironstones.



(1)a) *Elonichthys robisoni*
b) Flank Scale



(1) *E. robisoni*

Many of the shales exposed on the beach contain hard lumps of ironstone, commonly referred to as nodules. It is within certain of these nodules that the fishes are preserved.

Although complete specimens of the larger species have to be collected from embedded nodules, parts of fishes and smaller specimens may sometimes be obtained from nodules prised free by wave action and strewn about the shore. At best only around 4% of naturally occurring nodules at Wardie contain fish, this percentage has been reduced further by selective collecting over the years. It follows that the effort employed to successfully retrieve fossil fishes from the muddy rocks at Wardie is progressively increasing with time. Hearkening back to one fine morning in September 1971, the Wardie muds filled two bags for me in less than three hours. With ten fish nodules bulging in each bag, one foot stinking in each wellie and seabirds chorusing in each ear, I laboured ashore, saturated in satisfaction, tired in triumph, just in time - to miss the bus home! Then who cares when you've experienced a morning of overwhelming exhilaration. Fossil hunting is all about extinction, including extinction from the mind of everyday worries. There's always another bus....eventually!

The common fossiliferous nuclei in the Wardie nodules are coprolites, droppings of the elusive fishes we seek. Nodules containing these faecal pellets are normally smaller and more round than those which house their defecators. When cut and polished some of these produce interesting and decorative cross-sections: Ideally a coprolitic core ringed with 'brassy' iron pyrite and complemented with white radiating cracks infilled with calcite. (See illustration Page 17, Fig. C)

The ironstone is also the preserve of spectacular contemporary plant remains, but these are unfortunately very rare. Well preserved and more readily available are carbonised plant fronds fossilised within the shales themselves. Splitting the shale is easy enough but as the plant remains are black and the shales very dark, spotting these fossils requires concentration. Wetting your split shale and angling your hand-held slab in the light often helps enhance the contrast of dark shades between fossil and rock.

TABLE 1 The Wardie Vertebrate Fauna

Ray Finned Fishes
Rhadinichthys ferox
Rhadinichthys ornatissimus
Rhadinichthys carinatus
Rhadinichthys brevis
Elonichthys robisoni
Elonichthys striatulus
Cosmoptychius striatus
Nematoptychius greenocki
Gonatodus punctatus
Eurynothus crenatus
Wardichthys cyclosoma

Lobe Finned Fishes
Rhizodus hibberti
Megalichthys sp.
Rhabdoderma ardrossense
Acanthodian Fish
Acanthodes sulcatus
Sharks
Tristychius arcuatus
Diplodoselache woodi
Onychoselache traquairi
Amphibian
Lethiscus stocki

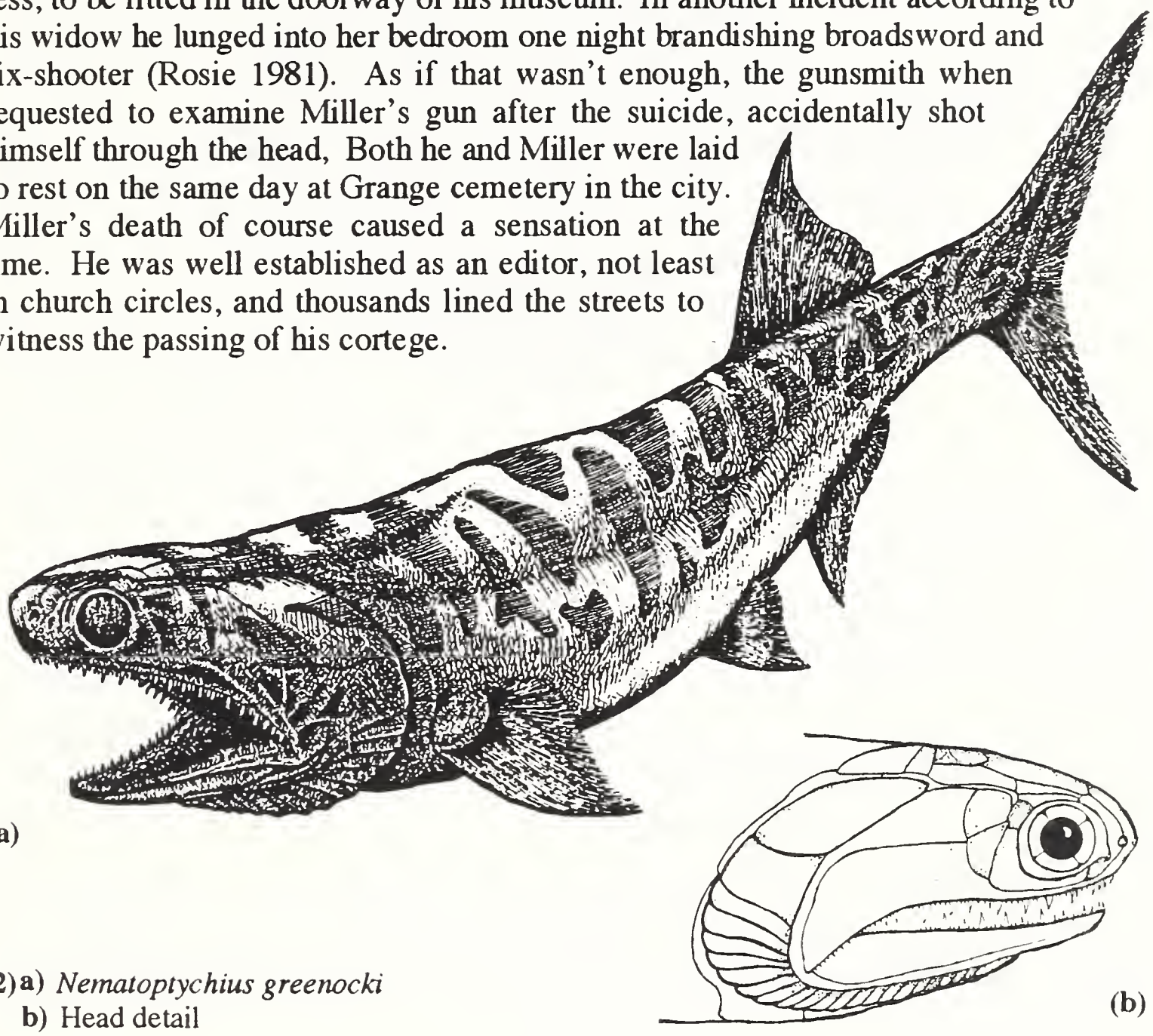
WARDIE AND PAST COLLECTORS

As John Knox stirred religious changes in Edinburgh, mineral workings at Wardie were placed on a commercial footing by the drafting of a charter in 1580 involving the Wardie coal. Workings must have extended well underground for by 1672 fire was reported to be disrupting operations in the one metre thick seam (Tait 1925). Apart from domestic use the main coal consumer was the salt pan industry, a major employer around the coasts. Mining here hit bankruptcy in 1829, but five years later Lord Greenock (whilst collecting fossils?), suggests the coal was still being worked. However this may have been unauthorised erratic mining by the locals. The ironstone (siderite) nodules are known to have been worked since the 1700's for pig iron smelting at the Carron Iron Co's works at Falkirk. One wonders how many fish were metamorphosed into pigs? After exporting successfully for more than two centuries this proud company folded lately in the 1980's.

The first recorded collection of fossils from Wardie was made in the mid-1820's by Lord Greenock whilst military governor at Edinburgh Castle. Reported to have been made 'not far above the Wardie coal' we may now deduce his earliest discoveries were recovered from Band 2 (the Wardie fish bearing shales are sub-divided into 'bands', see diagram at end of this section),but a number of *N. greenocki* (**2**) fossils formed part of his lordship's collection upon whom the species was named. He must surely have been engaged elsewhere on the shore for as far as we know the species is extremely rare in this band. He was certainly well engaged some years earlier when he had no less than three horses shot from under him during the Battle of Waterloo (Andrews 1982). The Swiss geologist Luis Agassiz examined Lord Greenock's fishes describing four species in 1835 including the type specimen of *A. sulcatus*. The latter although available to Traquair in 1890 at Oxford, is now unaccountably lost (Miles 1970).

In mid-Victorian times the Scottish writer, naturalist and former stonemason Hugh Miller collected the holotype of *R. ferox* as well as other fishes at Wardie. Many of his best specimens are now in the collections of the National Museums of Scotland.

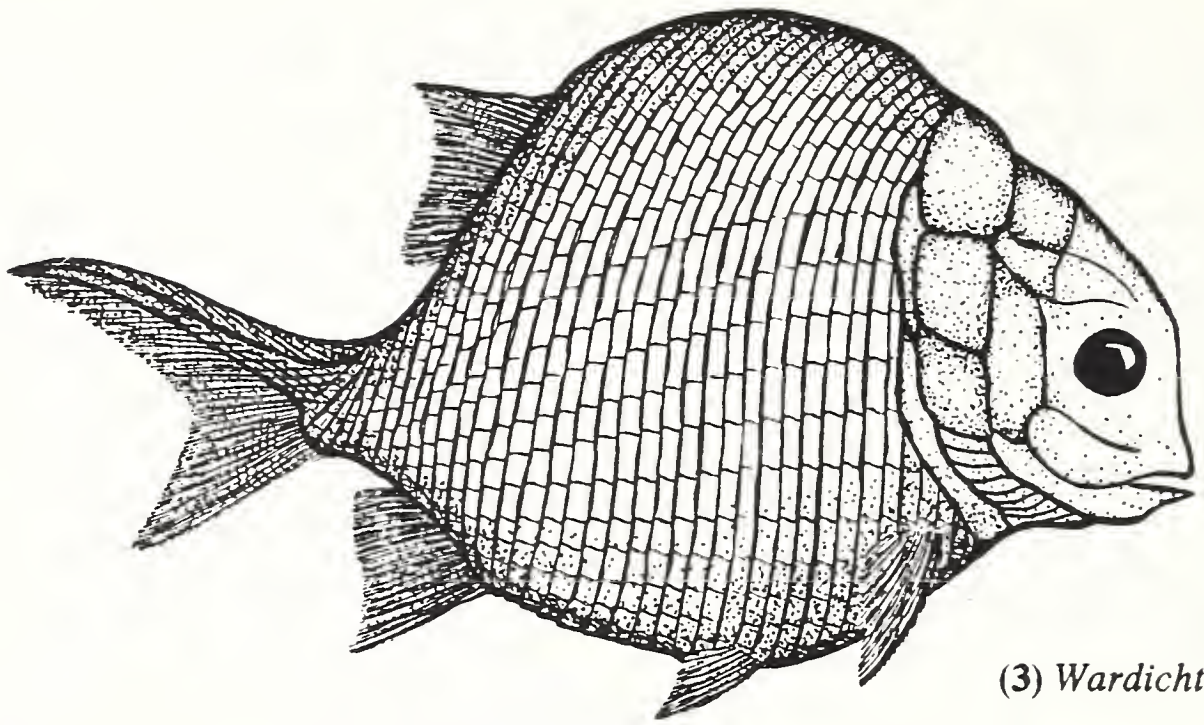
Miller in his later years lived along the coast at Portobello when his extraordinary intellect began to falter culminating in suicide in 1856. Perhaps mentally unbalanced beforehand, he portrayed unmitigated fear by ordering a mantrap no less, to be fitted in the doorway of his museum. In another incident according to his widow he lunged into her bedroom one night brandishing broadsword and six-shooter (Rosie 1981). As if that wasn't enough, the gunsmith when requested to examine Miller's gun after the suicide, accidentally shot himself through the head, Both he and Miller were laid to rest on the same day at Grange cemetery in the city. Miller's death of course caused a sensation at the time. He was well established as an editor, not least in church circles, and thousands lined the streets to witness the passing of his cortege.



(a) (b)

(2) **a)** *Nematoptychius greenocki*
b) Head detail

One of the great palaeoichthyologists of the later 19th century, Ramsay Traquair, not only collected fishes at Wardie but described most of the species, updating Agassiz's earlier descriptions. His monograph (1877-1914) on ray-finned fishes of the Carboniferous period and many of his other papers are still widely referred to over a century later. His writings certainly inspired me and I would encourage others of serious bent in Scottish fossil fishes to do likewise. He personally collected and described *W.cyclosoma* (**3**) from a single specimen he found at Wardie (specifically Band 6) around 1860. The generic name is not as is often thought, a reference to the locality, but rather in honour of Stephen Ward a contemporary collector of Carboniferous fishes from Staffordshire (collection in the Natural History Museum, London). Traquair is buried in Colinton Village churchyard with carved fishes flanking his headstone for company.



(3) *Wardichthys cyclosoma*

Thomas Stock, like Traquair who was Keeper, worked for a period in the Museum of Science and Art, Edinburgh, long since part of the National Museums of Scotland. He, above others in my opinion was the most astute collector of fossils around at that time. It was an unfortunate day indeed when Scotland lost Stock and many of his important finds when he emigrated lock, stock (excuse the pun), and barrel to the USA to take up a post at Harvard. He was a prolific collector on both sides of the Atlantic, Wardie being no exception. Four of his more important finds at the locality are outlined here:-

a) National Museum of Scotland Specimen

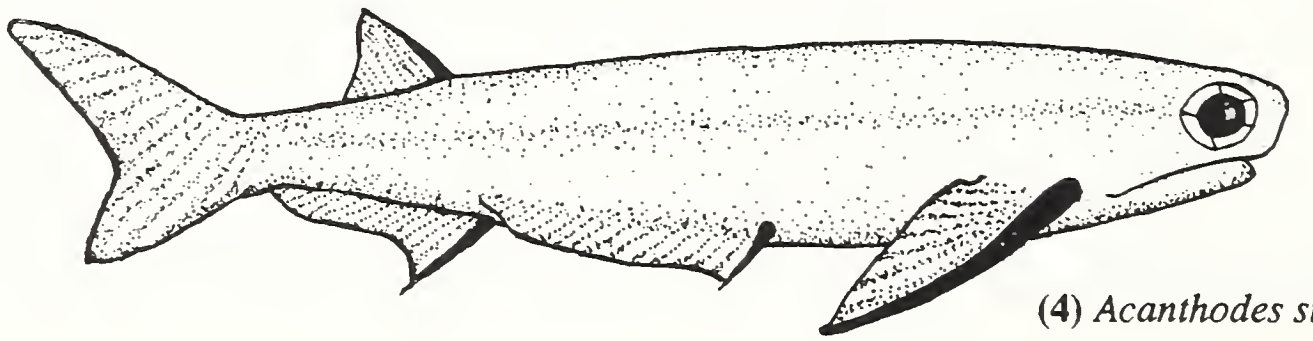
A second specimen of Wardichthys in 1880 from the same band as Traquair's initial specimen.

b) Harvard specimen

"A nearly complete" fossil *Rhizodus*, the huge lobe finned fish. Cautiously, I've not seen the remains, this may have been an exaggeration in Stock's part as the 'specimen' is in many pieces and in several drawers, all of which may not belong to one individual (Dr.S. M. Andrews, pers. comm.)

c) Harvard specimen

The most completely preserved vertebrate column of the fish order Acanthodida (Miles 1970). This is without doubt an important specimen of *A. sulcatus* (4) which, from an illustration of the slab, I suspect he collected from Band 7. (The provenance of Stock's find has been further convinced by the fortunate retrieval from Band 7 of a second specimen showing the anterior vertebral column).

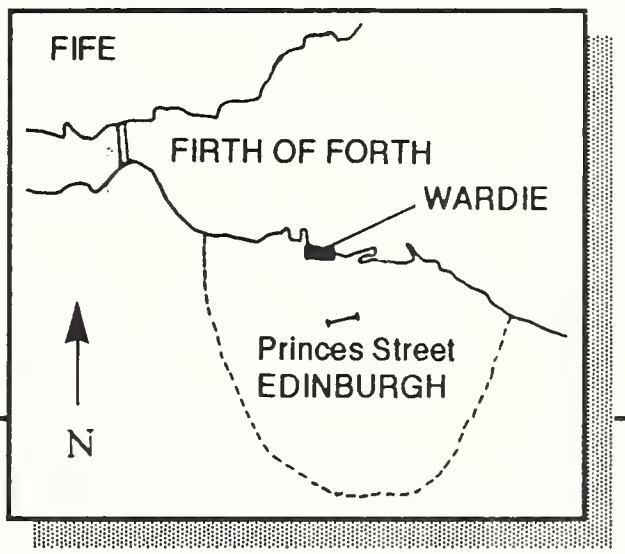


(4) *Acanthodes sulcatus*

d) Harvard Specimen

The holotype of *Lethiscus stocki* is still the oldest limbless amphibian ever found . Described by Wellstead (1982) one hundred years later, this single example from Wardie measures 49 cm. There are 78 vertebrae behind a small head contained in this sausage shaped nodule which I suggest from an examination of the fossil, was collected *in situ* from Band 6. Limbless amphibia from a later period contained well over 200 vertebrae indicating the Wardie specimen is incomplete posteriorly. Snake-like in appearance, *Lethiscus* was most likely a terrestrial creature, not an integral part of the immediate Wardie environment. This conclusion deems it an improbable find in future collections from the fish bands.

In contrast to the collecting popularity of the 19th century Wardie , like many other localities, was largely ignored for the greater part of this century. This augured well for yours truly and thanks to the subsequent erosions of innumerable tides during the long interim , a site with renewed virginity greeted my descent to the beach in 1969.



Sandstone
Coal
Nautiloids
Shales- no fish
Shrimps

X - Wardie Hotel
Y - 'Old Chain Pier' Public House
Z - Pumping Station

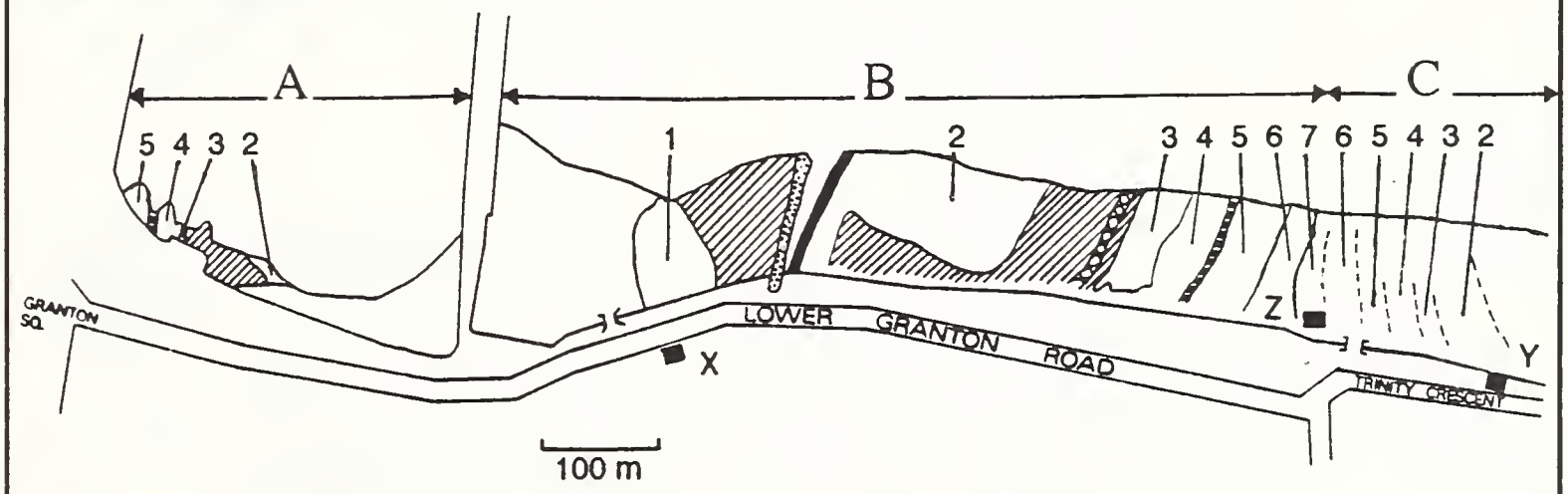


FIGURE C Approximate boundaries of fish bands and Areas A, B and C (as described below)

EXCURSION GUIDE

To visit the locality alight from the Lothian Region Transport bus in Lower Granton Road between the Wardie Hotel (X) and Granton square or alternatively 1 kilometre further east outside The Old Chain Pier public house (Y) in Trinity Crescent. Access to the beach is accomplished via a short walk at both. Using the former as a

starting point we arrive on the beach and may turn left to inspect Area 'A', or right for the extensive exposures offered by Area 'B'. As Wardie is a sheltered marine bay with muds 'wellies' are the most suitable footwear; please check the tides too, for exposures are sparse when the tide is high. In this regard the equinox tides of March and September are exceptionally low, providing opportunity to inspect little seen rocks (including the Wardie coal), and more time to appreciate others.

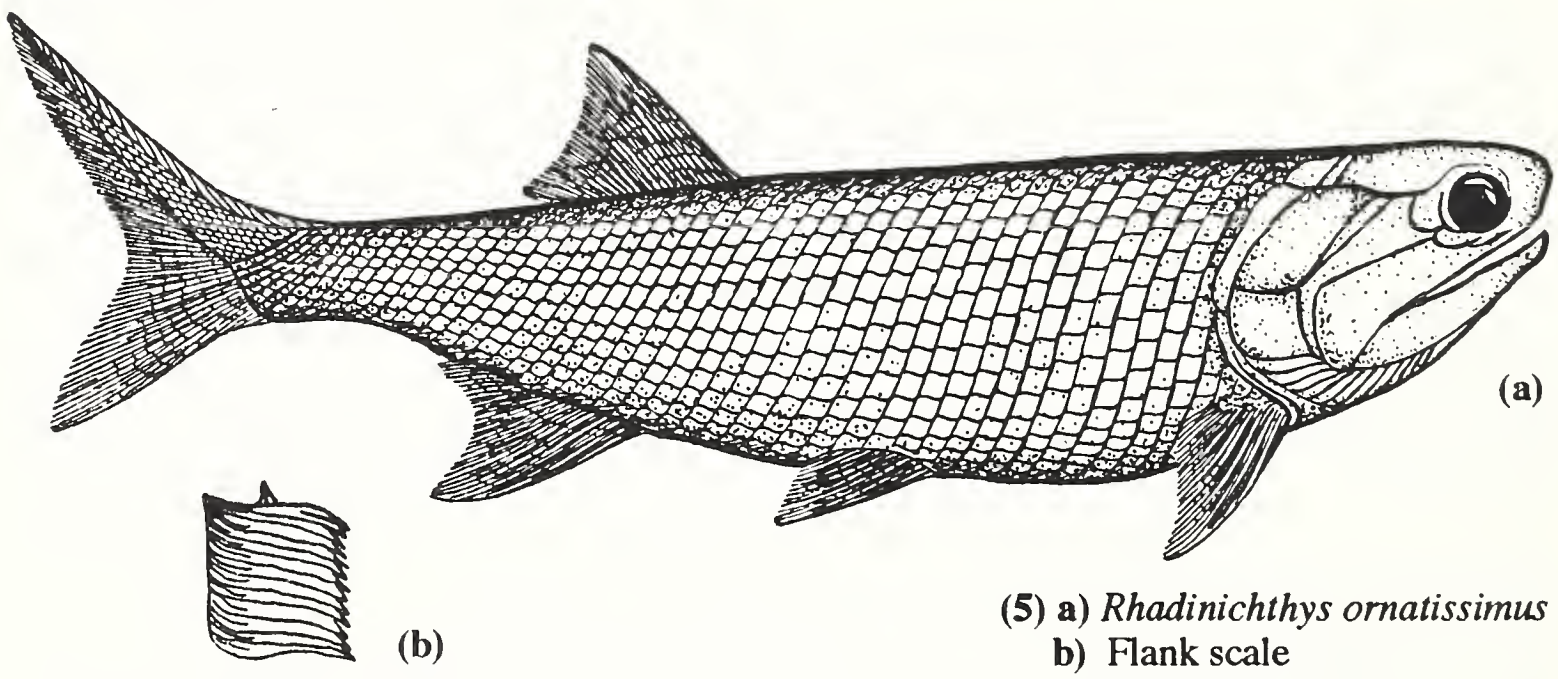
During our tour of the Wardie rocks I'll refer to 7 bands of fish bearing shale first described in 1975 in the Scottish Journal of Geology. Each shale band contains nodules peculiar to that band thus allowing the serious student of Wardie fossils to identify the band from which previously collected specimens originated.

AREA A

The rocks inside Granton Harbour include brief exposures of four fish bands (nos. 2-5) with pieces of red weathered ironstone from Band 2 strewn amongst the beach pebbles. In the south-east corner a rare example (for Wardie) of two fishes in one large nodule was obtained from Band 5 here; the other bands in the harbour have also enhanced my fish collection, my excitement and my income.

AREA B

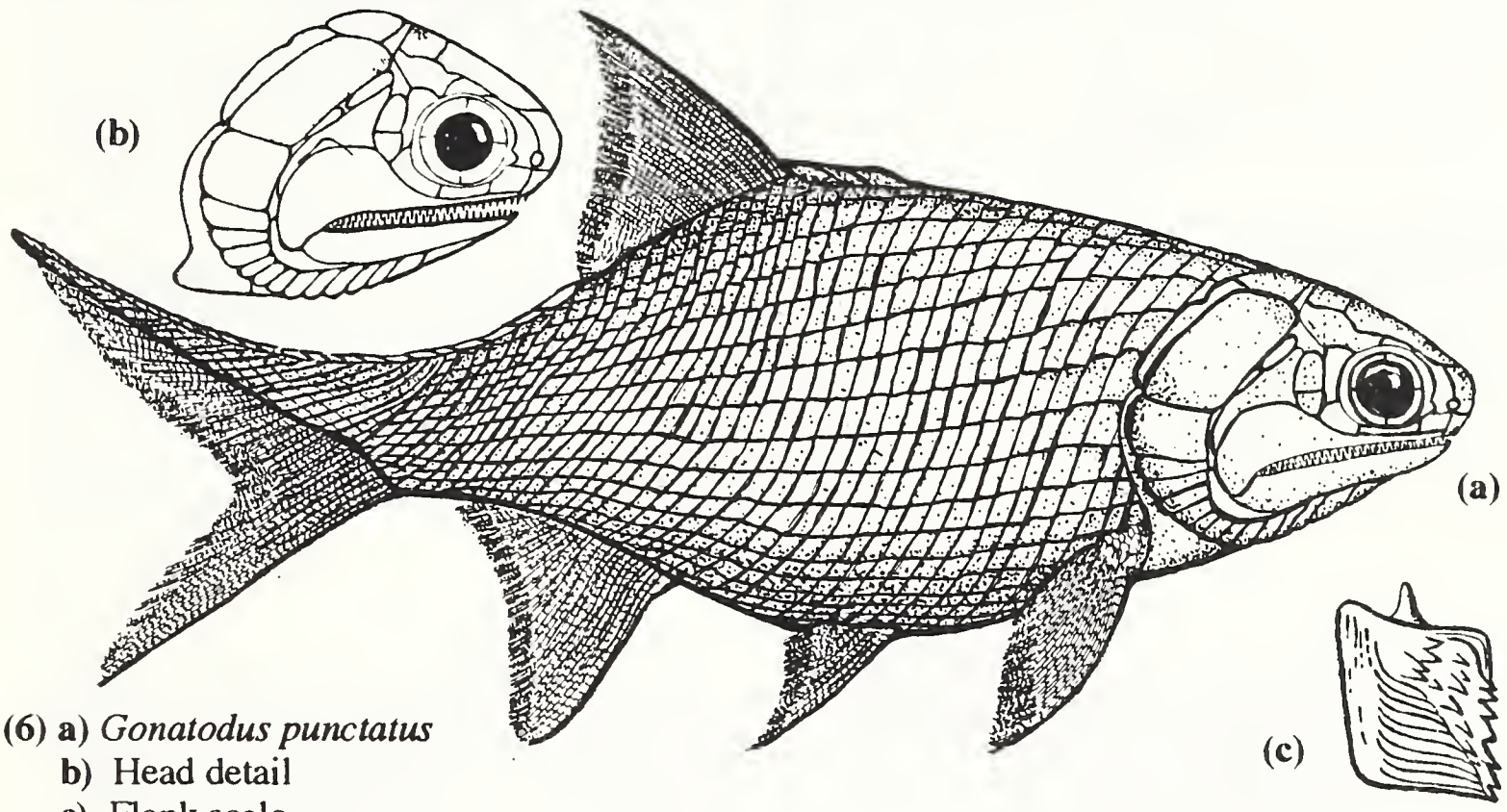
Further delights may be enjoyed by returning to the starting point where if exploring Area B from west to east, the sandy beach gives way to the smooth dark shale assigned to Band 1. This is the oldest of the Wardie shales observable and contains shallow nodules of various size. Most of the nodules contain brown/black mineralised coprolites with larger ones often housing two or more 'droppings'. I have collected a number of fishes from this band including *Rhadinichthys* **(5)** *Cosmoptychius*, and *Nematoptychius*.



(5) a) *Rhadinichthys ornatissimus*
b) Flank scale

Moving along eastwards unfossiliferous sandy shale is exposed over the next 100 metres or so. The unfossiliferous layers are capped by a prominent sandstone dipping east and situated opposite a bend in the high retaining wall above the beach. These

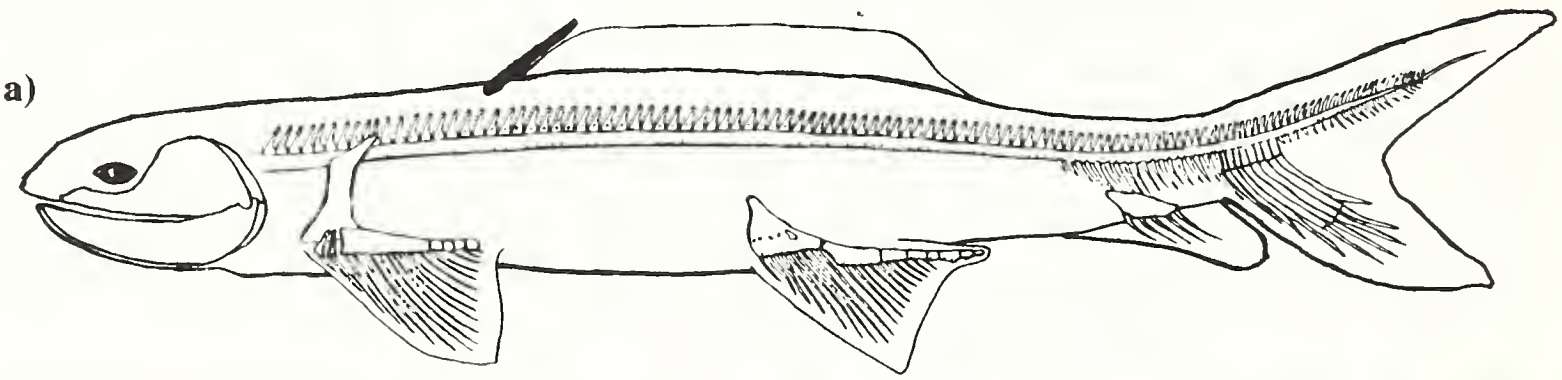
sandy shales, which coarsen up towards the sandstone, probably bear witness to progressively shallower waters. Indeed for a time, shortly after the deposition of the sandstone post, Lake Cadell relinquished its claim locally. The testimony here being a stand of trees in growth position having left casts of their fossilised stumps on the surface of the sandstone. This episode of forestation did not end with the immediate return of the lake, because a thin shale crammed exclusively with the stems of *Calamites* (an ubiquitous Carboniferous plant) overlies the sandstone. This suggests the forest was replaced by plant or shrub thickets with the ground hereabouts becoming increasingly waterlogged. Confirmation of this is inferred by a thin coal seam which in turn rests upon the *Calamites* bed. Unfortunately we cannot view this coal (except twice a year) as the outcrop has been worked out at the surface, but its position is marked at right angles to the shore by a watery depression partly filled with mussel shells and beach debris.



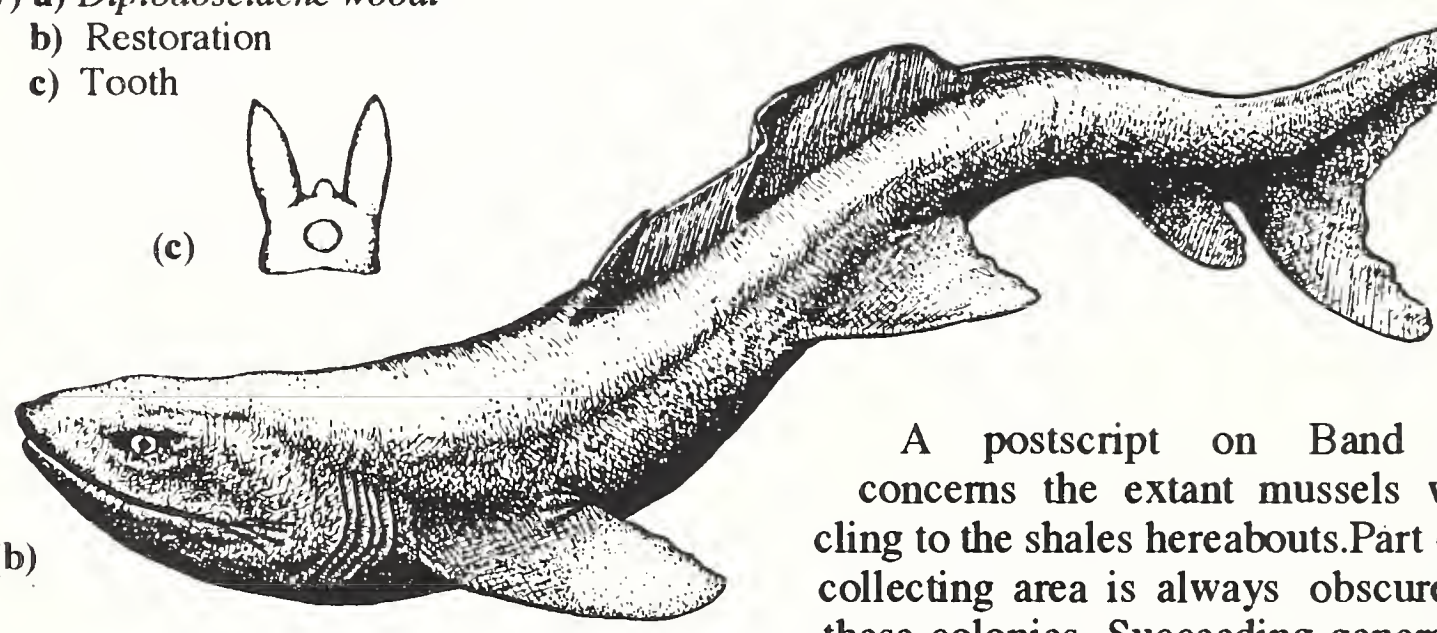
(6) **a)** *Gonatodus punctatus*
b) Head detail
c) Flank scale

A limestone with fish scales and ostracods (a tiny crustacean species) roofs the coal and indicates the lake's return. This limestone too is buried under the debris mentioned above although loose blocks are occasionally found in the vicinity. Immediately east of this gap, over a broad expanse of the shore , dark shales are exposed at low tide. These re-introduce us to the same parcel of rocks we examined inside Granton Harbour. Band 2 comprises only the basal three of metres of nodular shale in this expansive exposure. Typically Band 2 nodules contain brown coloured coprolites whilst some of the larger irregular examples confine several coprolites or occasionally uncrushed stems from a contemporary tree named *Pitus* (pers. comm. Dr A. Long). The fishes themselves are black in colour and are surrounded by a distinctive halo of white speckles (originally gas bubbles?). Often the heads are little crushed and the bodies in the majority of specimens are complete and undisturbed.

Black coloured fossil fishes from Band 2 may be converted to an attractive 'mauve' by prolonged exposure (see postcard). On rare occasions fish nodules will be found in this band where the halo of white speckles is present, but simply surrounds the position of the fish, the body fossil having failed to mineralise. These examples have no weakening nuclei and are therefore very resistant to hammer blows. In its time Band 2 has produced some really handsome fossils, the medium sized fish *Gonatodus* (**6**) being one of the most frequent of the fishes occurring in this deposit. Two specimens of the primitive shark *Diplodoselache* (**7**) were collected here in the 1970's. Described by Dr. J. Dick in 1981, *Diplodoselache* was a "medium sized predator up to 2 metres in length which inhabited the surface waters of the lagoon"(Lake Cadell).



(7) a) *Diplodoselache woodi*
b) Restoration
c) Tooth



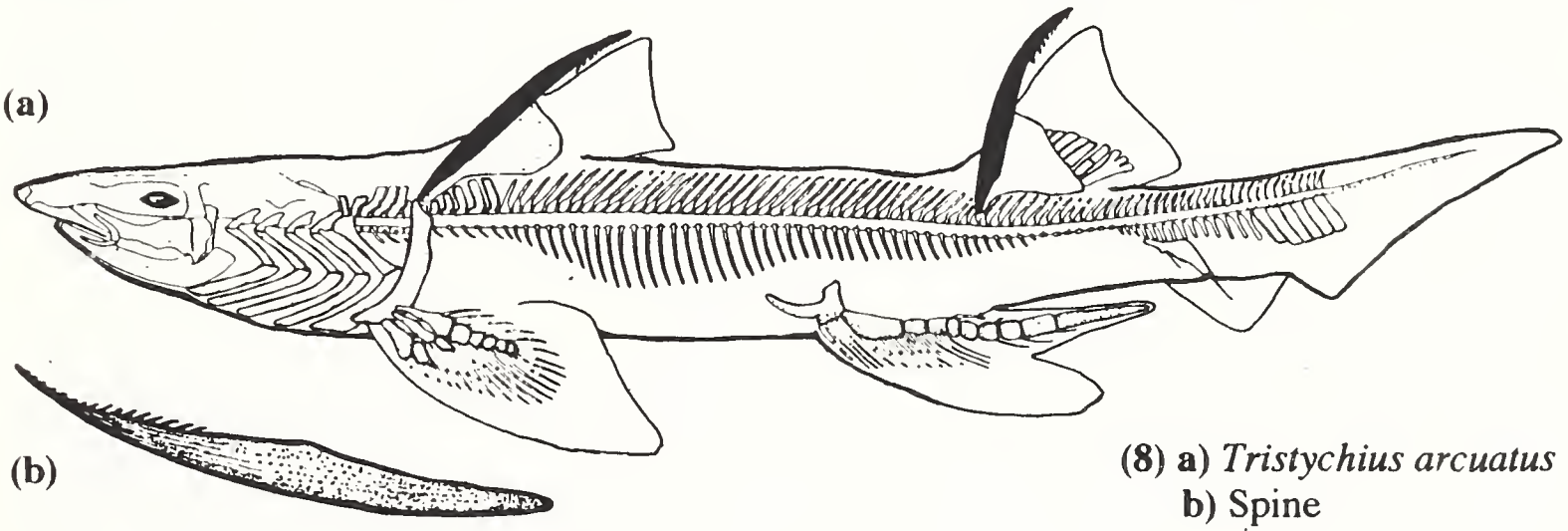
A postscript on Band 2 concerns the extant mussels which cling to the shales hereabouts.Part of the collecting area is always obscured by these colonies. Succeeding generations attach themselves until at some point the whole colony, many square metres in area and often 20cm thick, loses anchorage. By observation this cycle takes between 5-10 years depending on circumstance whereby the involuntary transit of this hitherto sessile community is apparently governed by the death and consequent loss of grip by the basal pioneers on the host rock. Thereafter the first full blooded storm sweeps them *en masse* clearing a fresh area for years inaccessible to the fossil collector. Conversely colonisation of a long exposed shale nearby gets underway, in turn thwarting future collecting there for a similar period . It follows that random visits to Wardie with extended intervals between may reward the avid collector with an unfamiliar rock exposure garnished by the thrill of expectancy.

On top of the Band 2 lies a flaggy (sheet like) shale with an absence of ironstone nodules. Unlike the coprolites contained in the fish band nodules which have a

spiralled cross section and show the undigested remains of a carnivorous diet, the coprolites in the flaggy shales are unexciting featureless black pellets commonly situated in profusion on the same plane. To my knowledge fossil fishes have not been recovered from this sequence. Near the top of the flaggy shale however, some 200 metres east of the sandstone, a paucitic layer of marine fossils are present. These fossils, nautiloids both straight and coiled forms, are limited to about 2cm of shale similar to the rest of the sequence. The apparent continuity of lithology (rock type) deems this precise fossil plane difficult to distinguish from its neighbours. Certainly it doesn't help that its compliment of fossils are sparingly distributed and that our old enemies the mussels may be in residence on this limited marine estate.

Eastwards along the shore from the nautiloid exposure, the top of the more resistant flaggy sequence is marked by a change in lithology to shales less resistant to weathering. From this point eastwards the low tide shore is occupied by five fish bands (nos.3-7) forming an uninterrupted shalely succession as far as Trinity Pumping Station, a concrete 'fortress' rooted on the seashore. These nodular shales by comparison with the flags are well worn down and only exposed for lengthy spells during the optimum period for low tide

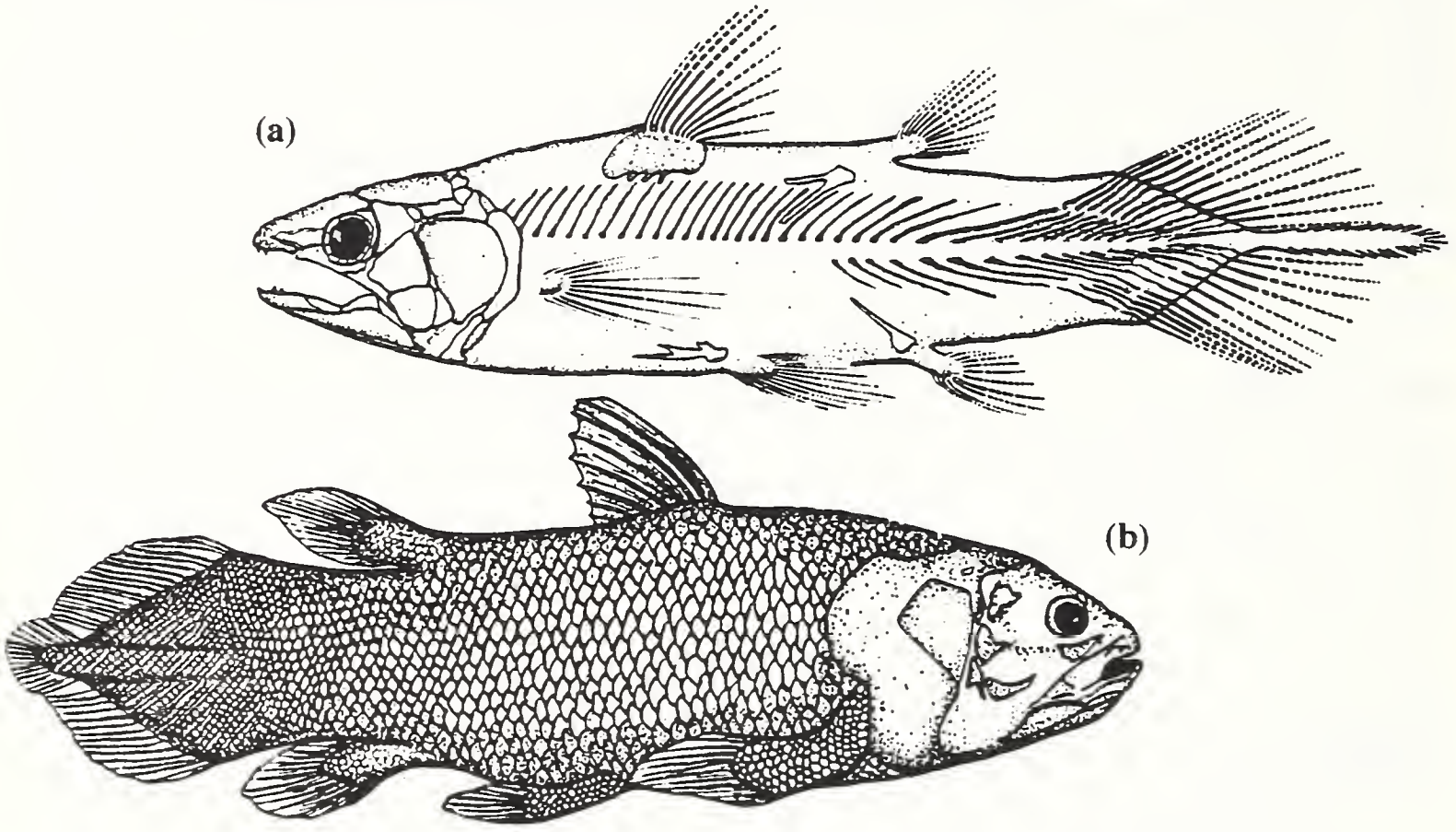
From west to east this fossiliferous sequence greets the visitor firstly with Band 3, a grey shale with shallow banded nodules. These nodules which weather brown on their exposed upper surfaces, are mostly barren, although a few of the slightly 'fatter' ones do house coprolites. In Band 3 ,which is less than a metre thick, fishes are very rare but it may be encouraging to mention that my best specimen of the shark *Tristychius* **(8)** was collected from this band. He (genitalia preserved) was collected at midnight, torch assisted, whilst still under 20cm of water due to a reluctant tide.



(8) a) *Tristychius arcuatus*
b) Spine

The dark shale of Band 4 with its numerous deep nodules is easily recognised, contrasting well with its paler sister immediately below. Body fossils are black in colour with the stomach area of the fish commonly 'exploded'. Nodules weathered maroon betray the presence of Band 4 by sitting proud in the shale close to the shore. Many have fused together forming long nodules with two or three pronounced 'bumps'. Within each bump resides a separate organic nuclei, normally a coprolite. On the other hand long nodules without bumps, but thicker at one end (the head) could provide you with the heart throbbing prospect of a large fish. If you're looking for

Nematoptychius to plug that gap in your Carboniferous fish collection then this is the band for you. This pike-like carnivore is emphatically not one of the smaller species at Wardie, but strangely in this particular shale it's one of the most common.



(9) a) *Rhabdoderma*, fossil coelacanth, Wardie
b) *Latimeria*, living coelacanth, Indian Ocean

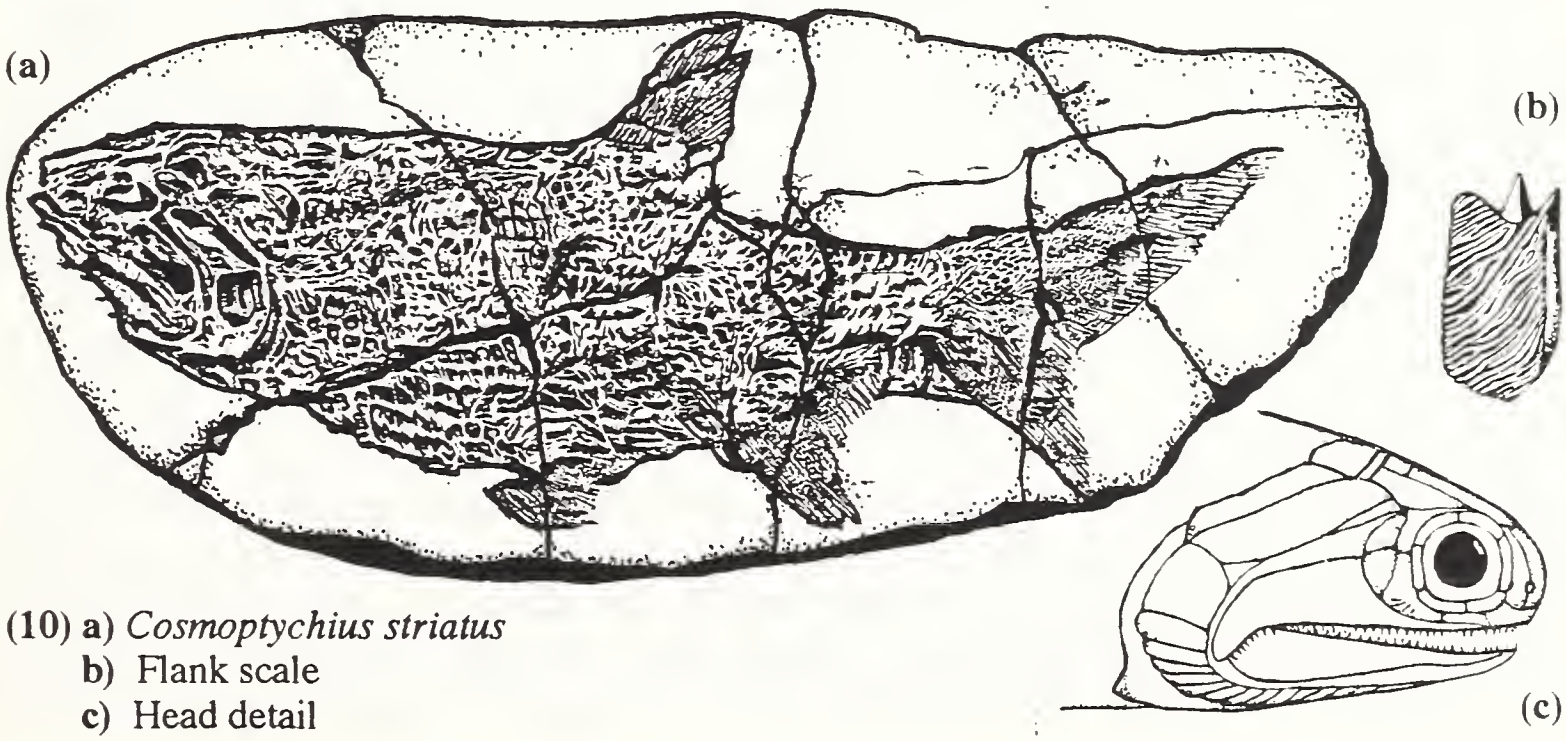
A thin (c.10cm) dark grey limestone marks the boundary between fish Bands 4 and 5. That this was another brief encounter between sea and lake is underlined by the presence of the fossil shrimp *Crangopsis* within the limestone. These crustaceans are contained near the middle layers of the limestone, their cuticles are preserved black which contrasts quite well with the grey background in the host rock. They normally occur as individuals, not in shoals.

Resting on the limestone and dipping gently east the basal shales of Band 5 can be traced seaward running at an oblique angle from the shore. These basal members of Band 5 are paler than the upper members of the same band which in contrast are almost black. In retrospect I should have assigned these contrasting members separate band status when erecting my original subdivisions in 1975. suffice to say that both members constitute Band 5 with no intervening strata and a thickness of 4.75 metres. The fishes in the lower members are usually brown in colour and the fish nodules somewhat slender. Some *in situ* ironstones in these basal shales are deceptively nodular, their form suggesting potential fish bearing possibilities. On sight they may raise your hammer to shoulder level and your adrenalin to danger level. Unfortunately they are not concentric around a nucleus, tending to merge with thin ferrous layers in the shales themselves. In short they are not the genuine article, harbouring nothing more piscivorous than red herring!

Black shales with black nodules represent the upper portion of Band 5. These nodules are broader than the former maintaining a generous margin of ironstone around each fossil.The largest fish nodule from Wardie to attract my gaze began her revelation as a barely perceptible bulge in Band 5. Initially draped in shale except for her head, which first took my eye, she was carefully stripped over the next two days until her fullness was exposed. Tape measure in hand I fell upon this fruit of my endeavours with understandable excitement, noting as I did so her 28cm waist and 1.2m length. She's twenty years older now, somewhat cleaner and reclining in her drawers at the National Museum of Scotland, a shapely shark indeed!

If the patchy outcrops of Band 5 were just about muddy enough for your toleration levels the situation deteriorates next door at Band 6. Twenty years ago things were even worse: Muds were thicker, more obnoxious, and decorated by the discardments of an affluent but very effluent city society. Thanks to the new pumping station raw sewage here is but a lingering memory in my nasal passages. I did have a nose for fossils that's true, but putting it in to practice here in competition with a multitude of alternative olfactory distractions, all rampant for affection, was decidedly taxing.

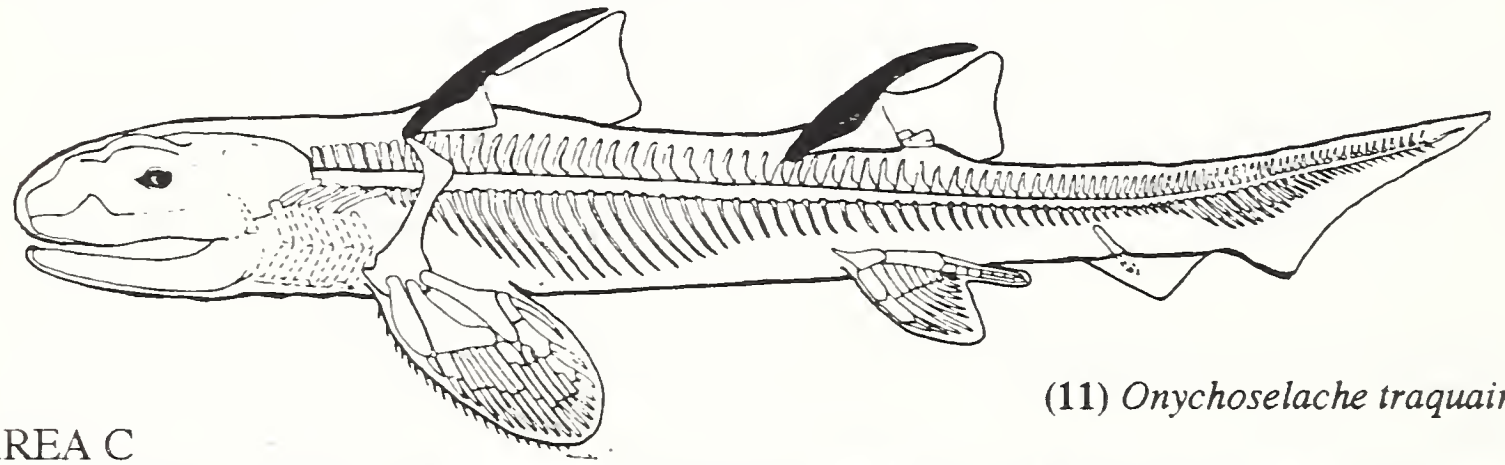
In the early 1980's construction work on the new pumping station threw up a good quantity of quarried shale from its foundations sunk into the shore rock. Over the ensuing few years these discarded shales have continued to break down revealing their hard nodular load. This circumstance by inference, affords todays collector more opportunity. However this is a double-edged sword as the loose shale now forms a mushy covering over most of the former exposures of Band 6 and indeed, has completely obscured Band 7. The fishes contained in the nodules here do not normally have wide margins of ironstone. In fact the outline of the occupant can often be appreciated by the observer without resort to a hammer or chisel. As aforesaid moderate to large fish nodules only remain intact whilst *in situ.* This is especially true in this band where the nodules have weaknesses in sympathy with the narrowest points in the fishes anatomy. Beautiful examples of *Cosmoptychius* **(10)** occur here in some nodules where the attractive brassy richness of iron pyrite persists to the very



(10) a) *Cosmoptychius striatus*
b) Flank scale
c) Head detail

extremities of the tail. In the ratio of nodules per tonne of shale Band 6 is the richest of the Wardie fish bands. Not only has it yielded the greatest number of specimens, but as a result has also provided us with the greatest variety.

It is unfortunate indeed that Band 7 for the moment is unavailable to us. Outcropping but temporarily obscured just a few metres west of the new pumping station, it dips steeply to the east and at right angles to the beach. Never well exposed even before rebuilding commenced, nonetheless the nature of its nodules and the quality of its fossils, must merit mention here. These nodules in particular reflect more compaction than other bands. The depositional banding of the shales is continued through the nodules with minimum deflection, thus horizontal trimming of the nodules is possible if desired. Despite their compaction the fossils are superbly preserved anatomically, and are black in colour with a little 'gold" or green pyrite mineralisation. The fossilisation of the axial skeleton of acanthodian fishes is a very important palaeontological phenomenon peculiar to this band. Forlornly, repeat forlornly, it may yet be possible to identify a few loose nodules from Band 7 in the vicinity of the outcrop. Their distinguishing features (from Band 6 examples), are the closely compacted banding and the wide margin of ironstone around each fossil. As further inducement I may add the only specimen from Wardie of a small shark named *Onychoselache* (11) he was obtained from a loose Band 7 nodule lying around here.



(11) *Onychoselache traquairi*

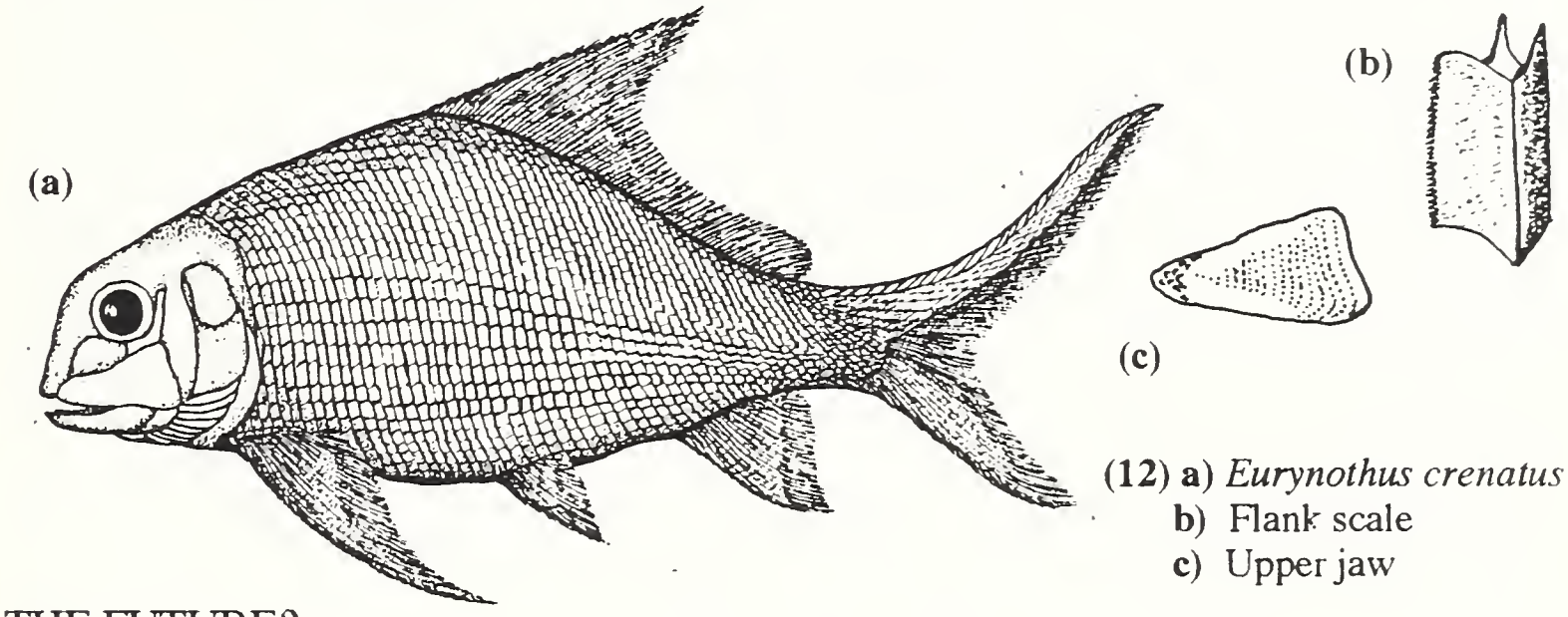
AREA C

On the other side of the pumping station (Area C) rock exposures in my lifetime have been very sparse. I used to be able to clear away beach debris where this was thin to expose the bedrock. In doing so I was fortunate enough to collect *Eurynothus* (12) *in situ* as well as others and more importantly to recognise they belonged to Band 2.

The identification of this exposure as Band 2 is of some interest as it reveals the local geological structure. The exposure lies about three metres out from the base of the sloping sea wall and a similar distance east of the ' Old Chain Pier' hostelry. Its position here and its south westerly dip suggest the rocks from this point back towards the pump house form part of the eastern limb of a syncline and the hypothesis is strengthened by the collection, in order of ascension i.e. younging from east to west, of Band 4 nodules, the shrimp limestone and Band 5 nodules between the hostelry and the pump house. This being so the Wardie coal though covered by debris should be at outcrop running onshore between the 'Old Chain Pier' and Newhaven harbour wall.

We who visit Wardie in the pursuit of fossils are a mixture of the experienced and inexperienced. You may have been here before and having seen, but not seen,

departed despairingly. Now, in reading this account you've realised that you're not in the minority! Wardie, her bounty not surrended but won, rhetorically throws down the gauntlet luring the challenger. To you who have suffered here, may I prompt you to return? To you who have succeeded here, I will wheel out some pertinent statististics in the Appendix, should you wish to merit your own Wardie finds in relation to others.



(12) a) *Eurynothus crenatus*
b) Flank scale
c) Upper jaw

THE FUTURE?

Recent private sector plans to develop Wardie Bay as reclaimed land have been objected to. The planners have withdrawn giving Wardie Bay as she stands, a reprieve into the foreseable future. At the risk of sounding old fashioned I feel this locality merits refuge from concrete landscaping, thank-you very much! Deservedly so, not only from the point of view (view being the appropriate word) of local residents or the sailing fraternity but equally on her merits as a natural history enclave. Scientifically Wardie's unique storehouse of fossils is internationally important in the light of current emphasis on fossil faunas and environments. Historically she has played a major role in the early development of palaeo-ichthyology and in the future should surely be given grace to offer the student and amateur alike the opportunity to prise yet more information from her.

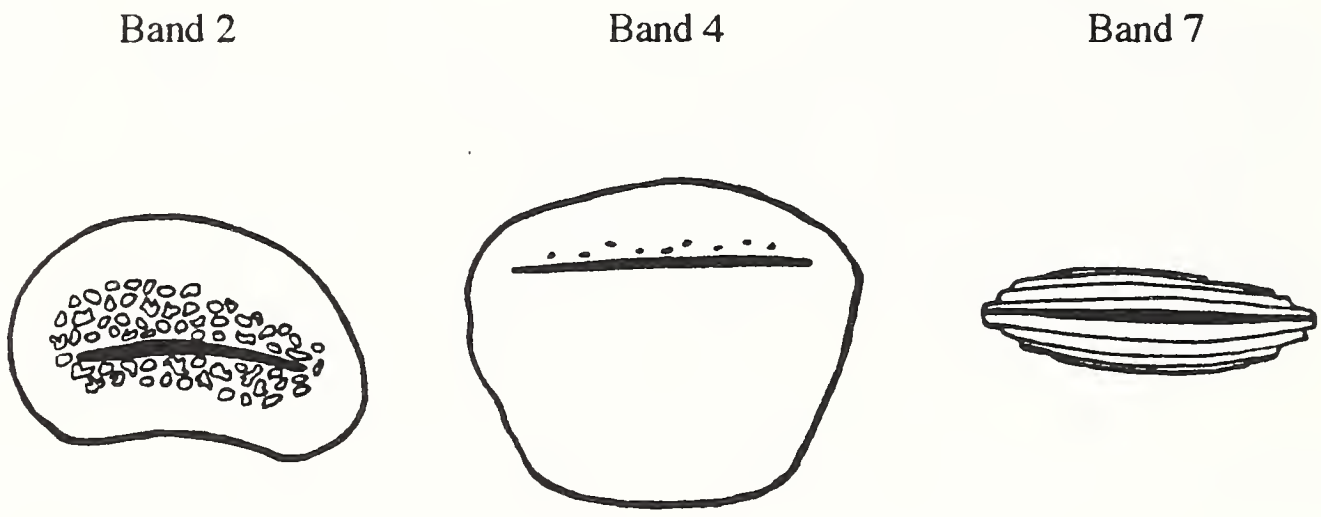
What then of the future and her clutch of civil developers? Well if by grace the shore remains, and waves come plucking as before, then Wardie will remain as she's always been, forever a rocky cabinent. A cabinet of tangible intrigue, with well stocked shelves but stubborn doors. Ah! those doors, those reluctant doors, for some alas their keys won't fit. Prehaps they're just a bit rusty, goodness knows there's enough ironstone lying around!

PREPARATION

When collecting a fish nodule *in situ* beware that the anatomical extremities of the fossil often extend beyond the ironstone concretion and into the shale. Particularly prone to this mode of preservation are the distal parts of fins especially the caudal fins of bony fish. In the case of the shark *Tristychius*, both the dorsal fin spines are only proximally preserved within the nodule as a rule, whilst the distal portions are preserved in the shale bordering the nodule. Wardie nodules collected from the beach

are invariably dirty. It's best to scrub each nodule under the tap then boil for a few minutes in an old saucepan, this will help kill bacteria from contaminated sea water. Realistically nodules will seldom, if ever, reach your kitchen stove intact. Because of their cumulative weight and bulkiness, it is practical to break your nodule in two parts on the beach. By examining the freshly exposed cross-section, the disappointment of arriving home with a heavy load of fishless nodules will be avoided.

FIGURE B Vertical sections of fish-bearing nodules.

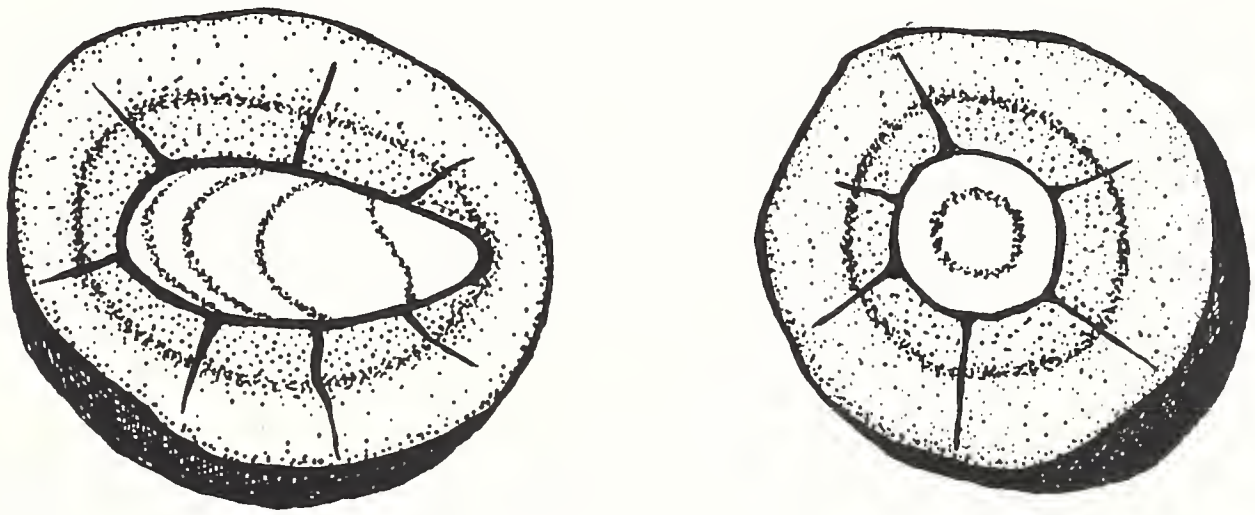


Your kitchen saucepan therefore will probably be boiling half nodules or smaller portions depending on how the original concretion fragmented. As a rule fish bearing nodules will break cleanly on receipt of a modest blow with the hammer. If on the other hand, you find such resistance that you are bludgeoning your nodule into submission, remember this is not the Spanish Inquisition, on the contrary your nodule is probably pleading truthfully that it does not harbour refuge to the fish fraternity. When at last an obliging nodule does offer you the sight of a fish in cross-section, reach round and pat yourself on the back. An acceptable alternative to this manoeuvre is to throw your hammer in the air and swear ceremoniously. Resume concentration by placing the two halves with a field note into a plastic bag. Avoid the temptation of proceeding to open each half on the beach as time is best spent by hunting for another suitable nodule, remember you're always fighting the tides here. Stooped one morning whilst absorbed in the hunt I glanced my jacket with house keys and bus fare, once draped over a large prominent boulder, now floating calmly offshore, The effluent element at that time rendered the water viscous in the extreme, with the ten metres between us occupied by a sea too thick to swim yet not firm enough to tread. It was a long walk back home that morning!

Back to your kitchen or workshop; place the round edge of your half nodule in a V-shaped holdfast and position a shallow chisel against the fresh cross-section in line with the plane of the fish, namely part and counterpart. My preference in fixatives carries the trade name "Dunlop Thixofix". This product is not available in most of the

large DIY stores but if you telephone the manufactures in Birmingham (021-373-8101), they will give you the address of your local stockist. More complicated nodules will require breaking into smaller pieces to reduce resistance prior to opening up along the fossil plane. Use smaller tools for smaller pieces to enable more precise manipulation and less damage during preparation. Heads can prove awkward to prepare satisfactorily, especially when they are preserved ' in the round' (little crushed). Often these specimens will split readily from the pectoral region immediately behind the skull, to just before the orbit (eye socket). The orbits being laterally opposed orifices, are infilled on burial by sediment which after mineralisation to ironstone, effectively rivets the skull. Overcoming this impasse employs different techniques according to circumstance. Basically the objective is to sever the source of the resistance without unduly damaging the snout region in front. This is where prior experience comes in to play, unfortunately experience refuses to manifest itself through the medium of print.

FIGURE C Sections through coprolitic nodules.

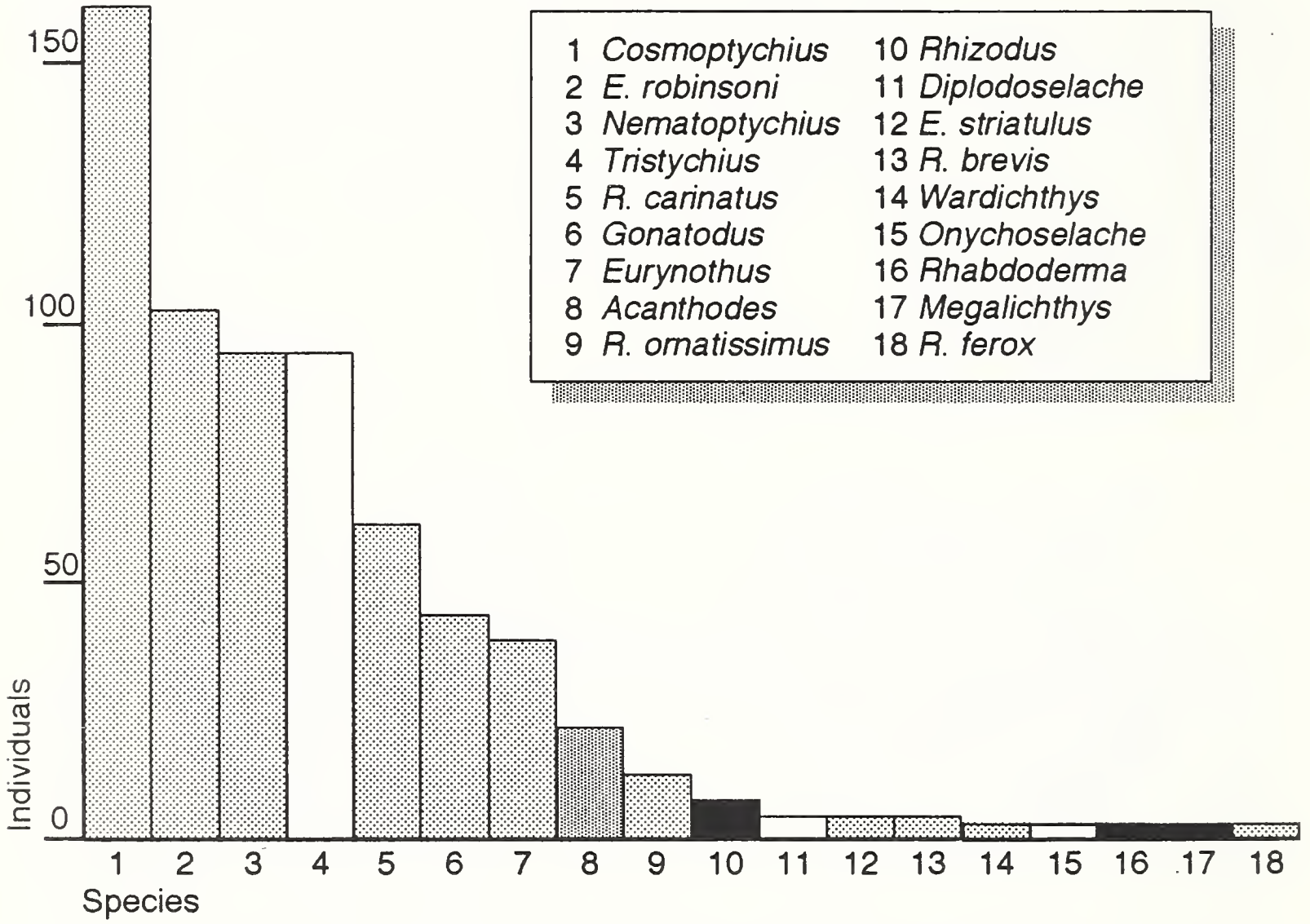


Slicing and polishing coprolitic nodules may prove an interesting alternative particularly if your fishing line has gone limp. From the beach chose a number of nodules which are likely to contain one uncrushed coprolite, these are smaller generally than fish nodules and more egg-shaped. Back home with your harvest, slowly cut each 'egg' in two with a diamond saw until you reveal a sectional view that pleases. Choice may be increased by cutting either horizontally or vertically. To obtain a mirror finish on your chosen surface laboriously hand grind using decreasing grades of powder on a smooth piece of plate glass. A coat of varnish is often applied finally but this is a matter of taste. Alternatively, the use of rock saws, polishing machinery, good company and friendly advice is available at local lapidiary clubs up and down the country, see yellow pages as they say, there are at least two in Edinburgh for example.

APPENDIX

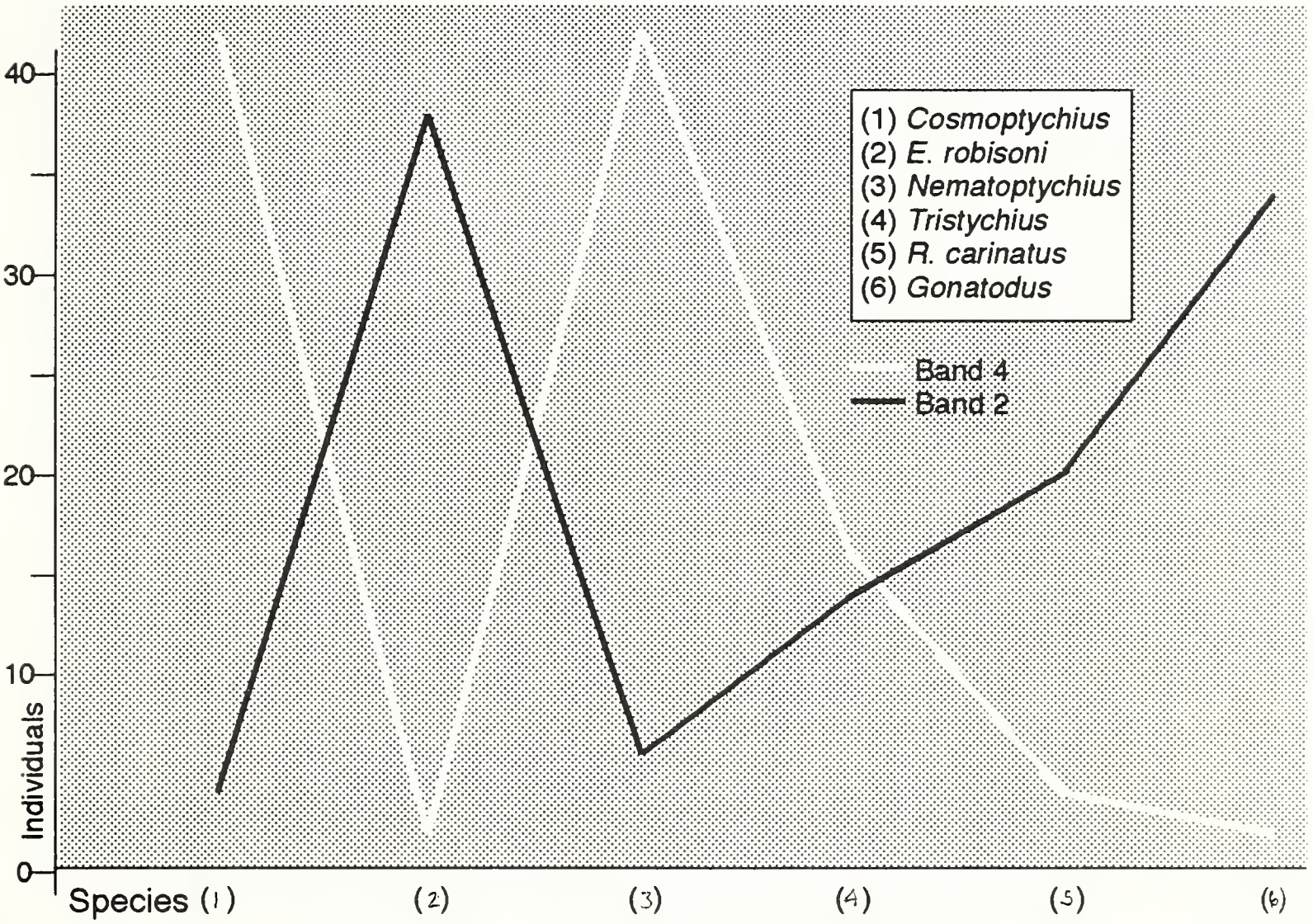
Comparative rarity of Wardie fossils can be measured on two planes, by comparison within the bands themselves, or by treating the locality as a single unit.

FIGURE D Relative abundance of fishes at Wardie (c.690 sample).



The usefulness of Figure D is limited to the interest of collectors and curators anxious to realise the rarity of specimens at locality level. The grouping of species abundance at Wardie under the umbrella of a fossiliferous bed is unrealistic, a compaction of time , a distortion of population dynamics, just a note masquarading as a story. All the fishes listed in Fig. D did, of course, not die in the same year, on the contrary individual swims were completed ten, twenty, or prehaps even a hundred thousand years apart. If attention is focussed on individual bands within the Wardie Bed changing population ratios can be recognised. These changes are not gradual, they are sudden and are followed by a phase of stability, the length of which is reflected in the thickness of each band. The reasons for changes in specific population dominance are unclear. Each band is too thick to be classed as a seasonal variation or as representing an abnormal year. Rather each band records phases of stability after sudden physical changes in the environment, aqueous or terrestrial and moreover that

FIGURE E Dramatic population contrasts recorded in Bands 2 and 4 using the top six species in Fig. D



these phases were long lasting. Alterations in salinity or sediment load content will effect the food chain and consequently populations of species . That these changes were moderate and not catastrophic is confirmed by the persistancy of the fauna in contrast to the sensitivity of the species.

Comparing Fig's D and E confirms that the former is little more than a faunal list. More to the point is that Fig.E indicates that each band represents a phase in the chronology of the lake, a separate environment with its own dicatates in which the macrofauna has responded in each case to specific criteria in arriving at ecological equilibrium. It may be significant (or just interesting) that the opposing configurations in Fig. E apparently involve the five ray-finned fishes only. *Tristychius* the elasmobranch (primitive shark) on the other hand maintains a marked consistency level in both bands despite the presumed change in circumstance and the intervention of time. The why and wherefore invites debate, suffice to say that *Tristychius* may be uryhaline as articulate specimens also occur in a marine band at Bearsden, near Glasgow, the others do not. The fact that its teeth were quite unlike the five ray-fins also hints that its niche was remote from their food web.

It's plausible that the present total of eighteen fish species at Wardie may yet be expanded by future collecting. Similarly these eighteen species (and more?) may be present in each band, albeit in differing population densities. In every fish band at Wardie faunal diversification is tending to increase with the number of fossils recovered, significantly the curve has not quite flattened out yet (Fig. F).

FIGURE F Fossil samples / species ratios

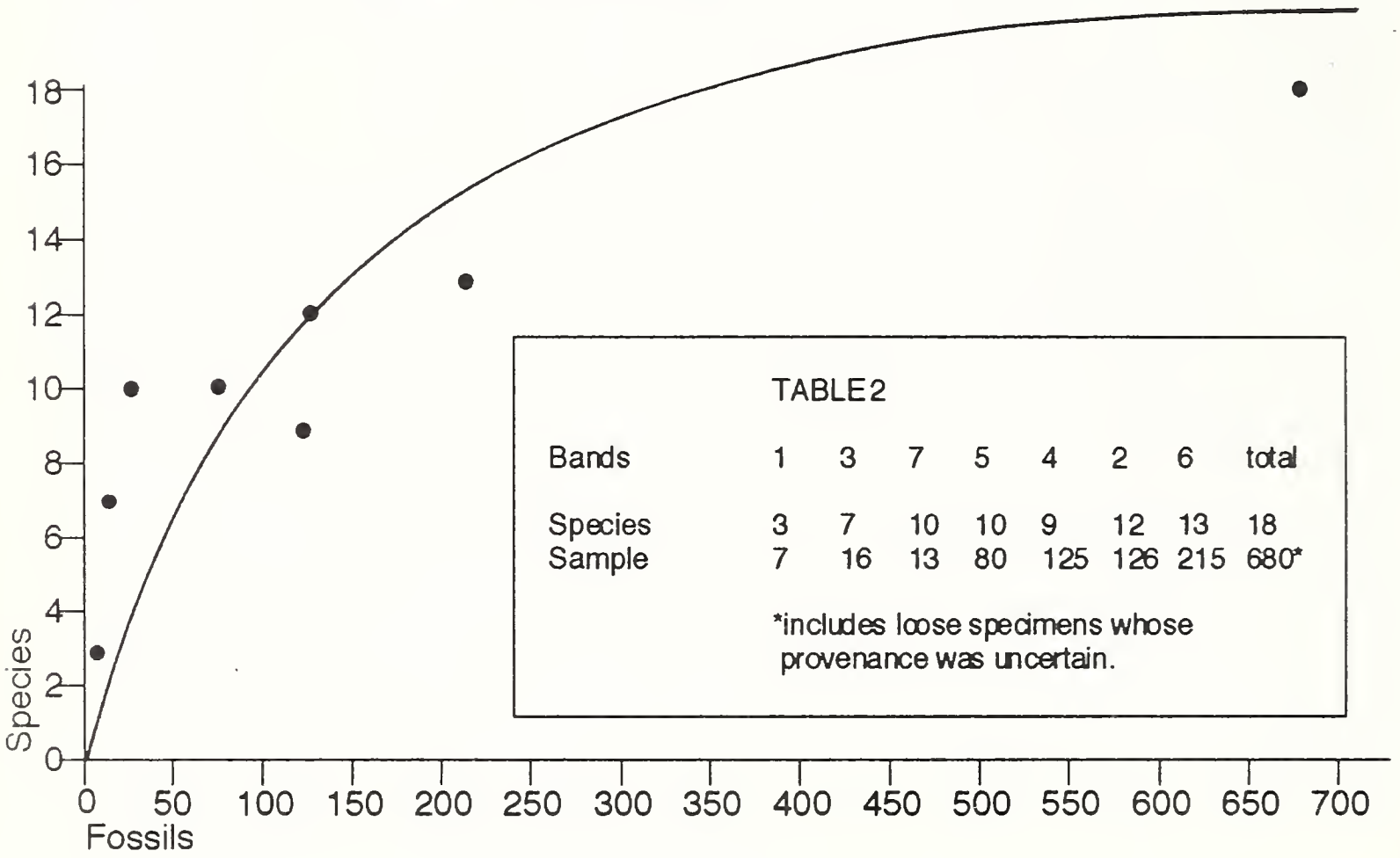


TABLE2

Bands	1	3	7	5	4	2	6	total
Species	3	7	10	10	9	12	13	18
Sample	7	16	13	80	125	126	215	680*

*includes loose specimens whose provenance was uncertain.

From a consideration of Table 2 it's reasonable to hypothesise that an entire Wardie fish fauna will include additional species not yet recorded. Prehaps if a thousand specimens from each band could be examined the entire fauna would be realised in each. Even so I recently collected over one thousand, six hundred fishes from a site in Scotland. In that generous sample thirteen species were realised, but one particular species was represented just once! Clearly then one thousand specimens from a single band may not reveal all species, but the same number from each band (seven thousand for the locality) probably would. If one species *Onychoselache* is represented by only one specimen, it surely poses the question, how many species still await discovery at Wardie? From these deliberations hopefully the seed of incentive has been sown, future collecting is desirable, nae encouraged, lest the debate falter and die.

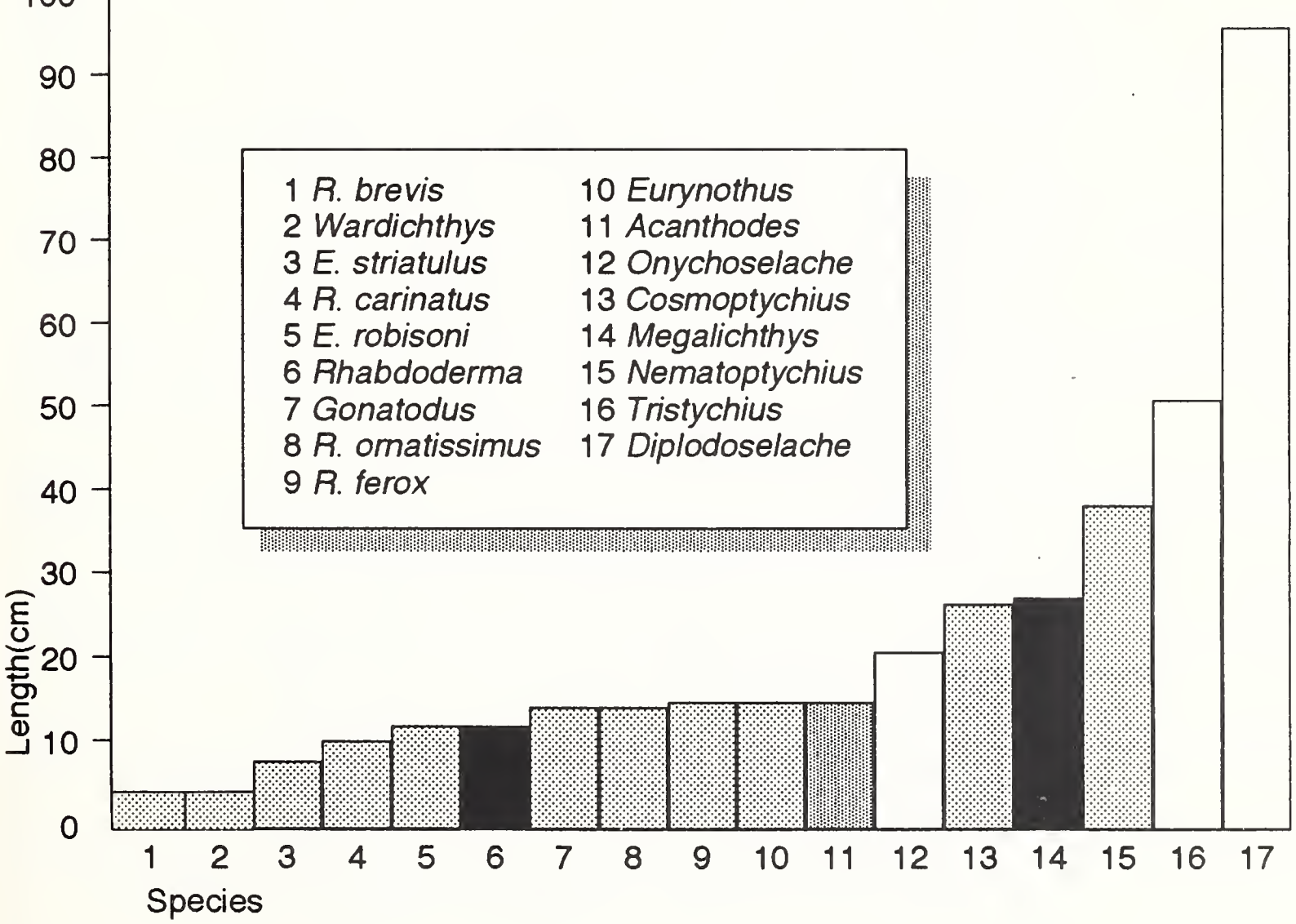
For guidance, in terms of productivity Area B has yielded most of my Wardie fish. The poorly exposed Area C has nevertheless yielded c90 specimens , the majority as loose nodules, and whilst I have no written record of finds for Area A my memory

estimates between 30 and 40, of which about half were *in situ*. Although I am active in the field elsewhere, Wardie is still a productive locality. Recent finds in the last couple of years justifying mention include a suite of specimens collected *in situ* from Band 2 by Dr. Tim Smithson, specimens from band 6 including the rare *Rhabdoderma* collected by Dr. Neil Clark, and a flank portion of the huge lobe finned fish, *Rhizodus*, found by Mrs. Pam Jenkins in a loose nodule at Band 2. Of the rarer elements in the Wardie fauna, *Rhizodus* so far as my collections go (i.e. three specimens from Area A and two from Area B), has only been found in Band 2.

Similarly *Wardichthys* is represented by one specimen from Band 2, although I've attributed both 19th century museum specimens to Band 6. Other anomalies at present are *E. striatulus*, from Bands 6 and 7 only, *R. brevis* from Bands 5 and 6, and *Megalichthys* and *Rhabdoderma* (**9**) from Band 6. it may be helpful if the casual collector and the academic worker had recourse to a data base where future finds could be recorded.

To those thirsting for an indication of the relative sizes between the various fish species , pray drink:-

FIGURE G Average lengths of fish species at Wardie Bay



A notable omission from Fig. C is the lobe fined fish *Rhizodus* and no wonder! This was the prince of piscivores, Lake Cadell's top carnivore which when fully mature, may have measured a lengthy six metres and more (Andrews and Westol, 1970). Unfortunately only portions of this huge fish have been found, but there's no better incentive to continue the search. All sizes given in Fig. C are based on averages at Wardie so do bear in mind that for each species, individuals have been and will continue to be found outside the norm. Many Wardie species spawned generations for a further 20 - 30 million years and their fossils have been found at localities younger and older than Wardie. Quite often the same species will have a different average size at seperate localities, especially those seperated by time, implying varied environmental pressures.

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(6) GARDINER, B.G. 1967 (a) (b) (c)

(7) COATES, DR. M. The Dinosaur Times No.2 1986 (a)
DICK, J.R.F. 1982 (b)

(8) DICK, J.R.F. & MAISEY, J.G. 1980 (a)
DICK, J.R.F. 1978 (b)

(9) FOREY, P.J. 1981 (a)
JESSEN, 1966 (b)

(10) TRAQUAIR, R.H. 1877-1914 (a)
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